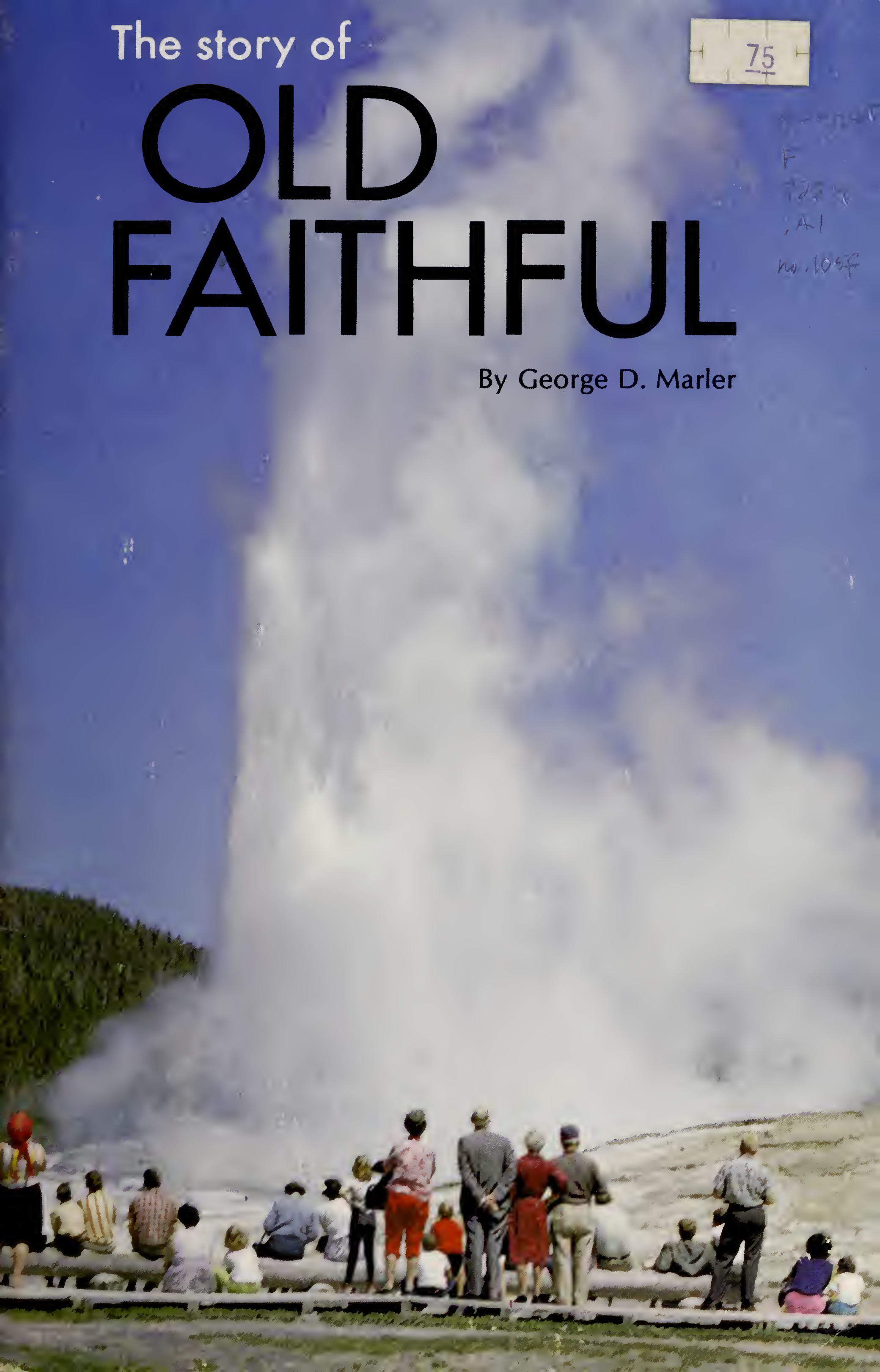
The story of

OLD FAITHFUL

By George D. Marler



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Cover Photo: Marler

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OLD FAITHFUL

By George D. Marler

Illustrated by Keith L. Hoofnagle

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STEP BACK INTO THE FOREST A MOMENT . . .

Let buildings, cars, roads and people disappear. Turn back a century ago and join the exploration party of Washburn, Langford and Doane as they start on horseback into the Firehole River valley.

" . . . Thinking the wonders of the Yellowstone country had been left behind, and anxious only to reach the settlements of the Madison Valley, the Expedition of 1870 was startled and astonished to see at no great distance an immense volume of clear, sparkling water projected into the air to the height of one hundred and twenty-five feet. 'Geysers! Geysers!' exclaimed one of the company, and spurring their jaded horses, they soon gathered around an unexpected phenomenon—a perfect geyser . . . It spouted . . . nine times during the explorers' stay . . . They gave it the name of 'Old Faithful'."[1]

To many people this geyser has become the symbol of National Parks, the focal point of visits to Yellowstone. Day after day, year after year it has continued to erupt since the 1870 expedition described it. Other large geysers have gone dormant; new ones have evolved. The intervals of many have changed. The predictability of most has varied. Old Faithful, consistent in its pattern, continues to erupt regularly enough so that park visitors wait the half hour to an hour that may remain until the next eruption.

In spite of Old Faithful's fame, its true character is shrouded in folklore and mystery. Popular and unfounded legends continue to circulate and be accepted by a great number of people.

There has been a long-felt need for a written exposition that briefly tells the story of Old Faithful geyser. This booklet is a synthesis of many talks given by the author at the cone of Old Faithful. It is our hope it will help correct false impressions held about this remarkable geyser, and enhance understanding and appreciation of Yellowstone's unique wonder.

CHAPTER I

OLD FAITHFUL OF FACT

Many visitors to Yellowstone Park believe Old Faithful erupts with time-clock regularity. The name itself contributes to this fallacy.

When Old Faithful was discovered in 1870 by the Washburn Party, it was believed to erupt at "nearly hourly" intervals. But they came to this hasty conclusion after only two days' observation.

Despite the party's error in timing, and subsequent documented observations to the contrary, Old Faithful's time-clock reputation stubbornly survives to this day in the minds of millions of visitors to Yellowstone Park.

Old Faithful is "faithful" only in that it does erupt, 21 to 23 times every 24 hours, but in tune with its own pattern of regularity.

Eruptions may occur within a time interval of only 33 minutes—or as long as 148 minutes. Only by coincidence does an eruption occur on the hour.

One fact is fairly certain. Since its discovery in 1870 Old Faithful has erupted approximately 840,000 times.

Photo: Marler

No geyser plays at set periods

A day's observation in Yellowstone's geyser basins reveals that no geyser, where consecutive intervals can be determined, has a set time of performance. All geysers vacillate in their eruptive times. The majority are characterized by great irregularity and seem wholly capricious in their play.

There are a number of geysers, like Old Faithful, whose functions follow a pattern in recurring frequency. While these geysers have been classed as *regular* in their action, it must be understood that "regular" is relative when referring to geyser activity. Any geyser whose pattern of eruption enables an observer to make an intelligent time estimate of its next play is classed as "regular." The degree of regularity varies for all geysers.

There are geysers in Yellowstone Park which perform as regularly as Old Faithful. A few, smaller ones, show an even higher degree of regularity than Old Faithful.

How regularity is determined

The regularity of all geysers is determined by noting deviation from the average time between eruptions of a long series of carefully checked eruptions.

Old Faithful's eruption intervals have been observed more closely than any other geyser's at Yellowstone. The first official check to determine the average period of eruption was made in 1872. Since 1920 the National Park Service has stationed park rangers at Old Faithful. One of their duties is to determine the time of each daylight eruption in order to predict for visitors the approximate time of the geyser's next performance. Each season (May through October) 1,200 to 1,500 eruptions are recorded. The seasonal average is determined from the combined season's intervals.

Misconceptions about Old Faithful

Most of the early literature published on Old Faithful—and some published today—implies that it plays with set hourly periodicity.

So firmly fixed is this idea of precision that many persons, even after a visit to Yellowstone Park and observation of one or more eruptions, leave with the impression of a set time of performance.

This deeply entrenched belief has given rise to other misconceptions. Some park visitors with preconceived notions about the geyser are perceptive enough to observe that Old Faithful's eruptive time varies. But instead of questioning their beliefs, they conclude Old Faithful is becoming irregular.

Many times each day rangers are asked, "Is it true Old Faithful is becoming irregular and slowing down?" Some people claim that during earlier visits the geyser played much higher and more regularly than at present. Attempts to rectify these misconceptions often are suspiciously regarded as apologies for Old Faithful's departure from the straight and narrow.

CHAPTER II

FREQUENCY OF ERUPTIONS

No man in the National Park Service can mingle with crowds in the geyser basins without being asked, "When will Old Faithful play?" If he replies, "I don't know," he's often met with a bewildered look.

Few visitors to Yellowstone Park realize that unless the time of the last eruption is known, there is little data on which to base a satisfactory prediction of the next. Even with this data, an unqualified prediction is not possible. No ranger will predict the time of Old Faithful's next eruption without a "may" or "about."

In the Old Faithful Visitor Center attempts are made to predict the time of the next eruption. The ranger-predictor allows himself a latitude of about 10 minutes. His prediction may state, say, 2:50 to 3:00 p.m. If the eruption does not come within the predicted time people often say, "Well, it was late that time," or "It played before it was due." It seldom occurs to them it was the prediction and not the eruption that was in error.

Photo: Marler

Duration of play influences length of interval

Until 1938 all predictions of Old Faithful were based on the average period. Following each eruption the predicted time of the next play was arbitrarily set ahead the length of the average period. Over- or under-average periods, constituting the majority of all intervals, were not accounted for.

During the 1938 season ranger-naturalist Harry M. Woodward made an important discovery: there is a correlation between the duration of Old Faithful's eruption and the length of interval between eruptions.

Old Faithful's eruptions range between one and a half and five minutes. They are timed from the first heavy surge which lifts water skyward until the last splash above the cone. The average eruption lasts about four minutes.

Generally, eruptions of average duration have an interval that is also near average. When the duration of the play is less than four minutes, the interval to the next eruption always will be under-average. Should the duration be short (say, two minutes), the next eruption will take place in much under the average time, often between 45 and 55 minutes, and occasionally less than 40 minutes.

The play at the end of a short interval is, with few exceptions, near five minutes duration. This results in an over-average length interval; the great majority of these eruptions occur between 70 and 80 minutes.

During some years the ratio of short intervals to long ones has been inexplicably higher. Occasionally, there are days when long and short intervals alternate. Recognizing past behavioral patterns greatly reduces the guesswork in predicting Old Faithful's eruptions.

CHAPTER III

ERUPTION OF OLD FAITHFUL

Old Faithful, like many geysers, gives signs of an impending eruption. From one to 30 splashes of water above the rim of the crater are the first indications of imminent activity. The time from initial splash until eruption may be as long as 30 minutes.

When the interval between eruptions is much over average, there are more preliminary splashes. But if the interval is near minimum, eruption takes place with little warning.

On rare occasions, an eruption will begin with the first burst of water above the cone. When this happens, the splash grows in force and volume, and within seconds rockets skyward a hundred feet and more. Usually, though, several splashes precede an eruption.

Occasionally, preliminary splashing delays an eruption. Following several splashes, often of growing forcefulness, one occurs which suggests eruption is starting. But for some reason the heavy surging may fail to trigger it. When this happens the eruption will be delayed five minutes or more.

When the light and weather are favorable, an eruption of Old Faithful is an awesome and sublime spectacle. The boiling-hot water, explosively jetted out of the earth, assumes a pronounced symmetry and gracefulness of form.

One would have to be dull and unresponsive to the unusual, the beautiful, not to be exhilarated by an eruption of Old Faithful. The myriads of water droplets with all the luster of brilliants projected against the intense blueness of a Yellowstone sky make it one of nature's superb creations.

Telling phrases by one of Old Faithful's discoverers strike a responsive chord in many appreciative visitors today: "The earth affords not its equal. It is the most lovely inanimate object in existence."[2]

Why Old Faithful erupts

There's a natural inquisitiveness about geysers. Why does boiling water shoot out of the earth in such great volume and at frequent periods?

Geyser activity depends on three conditions: water, heat, and a suitable conduit through which the water escapes. The conduit's special construction cannot be observed, but is inferred from our knowledge of behavior of liquids and gases.

No single theory seems wholly adequate to explain the overall behavior of many geysers, including Old Faithful. Two theories are discussed here to give insight into the subject. The Modified Bunsen Theory generally has been accepted since geysers first were studied over a hundred years ago. The more recent Deep Circulation Theory derives from new information from deep drillings.

Modified Bunsen Theory

Pressure determines water's boiling temperature. At sea level water boils at 100 degrees Centigrade, or 212 degrees Fahrenheit. At Old Faithful's elevation,

7,366 feet above sea level, water boils at a temperature of 93 degrees Centigrade or 199 degrees Fahrenheit. In addition to atmospheric pressure, water in Old Faithful's tube or well also is under the pressure of its column of water. This tube has a vertical depth of at least 75 feet before it twists off into the underlying rock. One or more fissures connecting with the tube probably go down to a depth of several thousand feet.

A 1948 study by Dr. L. C. Graton and associates of Harvard University indicates water enters Old Faithful's well from a side channel, or channels, above the 75-foot level. If so, it is somewhere along one of these side channels that the eruption starts.

When water is heated in an open vessel convection currents are set up. Heated water becomes lighter, rises to the surface, cools and sinks in the direction of the heat source. This convection results in a constant turnover of water, tending to equalize its temperature.

In Old Faithful, due either to side channels or a twisting, tortuous tube, circulation of water is prevented, or at least retarded from the point where the eruption starts. This interference with convection permits the water to be heated to higher temperatures. The rate of rise is governed by supply of heat from below—heat carried by ascending magmatic steam, according to the Bunsen Theory. With some geysers a neighboring spring or springs, with which the geyser has subterranean connections, also influence the rate of rise.

When water trapped in the side chamber nears the boiling point, steam bubbles form. Expansive forces exerted by the steam cause water to rise in the tube. When the rise is sufficient to reduce pressure to the flash point (boiling point) of the trapped section, eruption takes place. Thus an eruption is a steam explosion. Following an eruption, when the influx of water is again heated to a high enough temperature, another eruption takes place.

"Deep Circulation" Theory

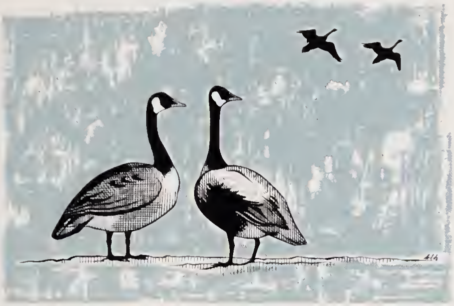
This relatively new theory involves deep circulation and heating of water to temperatures far above the surface boiling point. It is supported by the findings in Yellowstone by a team of scientists of the U. S. Geological Survey. The Deep Circulation Theory was first proposed by Dr. Donald E. White to explain the small natural geysers and geyser wells at Steamboat Springs, Nevada.

Data obtained from deep wells drilled at Steamboat Springs and other hot spring areas indicate that geyser water circulates to great depths—probably 5,000 to 10,000 feet below the surface. The water is heated mainly by contact with very hot rocks; the heat is probably supplied by conduction from molten magma located at even greater depths. Only a small part of the total heat is supplied by hot volcanic gases (in contrast to most other theories).

Deep in the circulation system, the water can be heated far above its surface boiling point because of the tremendous pressures. The driving force for deep circulation is *heat*. When water is heated, it expands and becomes lighter. The cold heavy water flowing down in the deep circulation system forces the hot light water on through and out of the system, as hot springs and geysers.

Water heated to 300°F or 400°F contains more than enough energy for eruption–it needs no local volcanic steam, because it forms its own steam by boiling as pressure decreases. Near the ground surface, the hot water is forced through narrow cracks and channels into the local plumbing system or "reservoir" of each individual geyser. Each plumbing system consists of a geyser tube and the channels and pore spaces that lead from this tube to the deep circulation system.

During an eruption, water is forced out of the tube much faster than new hot water can flow in through the narrow feeders. The hot rocks and superheated water are cooled as the extra energy is used



to form steam. After an eruption the water levels, pressures and temperatures are low, so a period of rest or recovery then is necessary. New hot water flows into and slowly fills the system. After filling (for geysers such as Yellowstone's Riverside), cooler water may flow from the top of the tube while hotter water flows in from below. Finally, temperatures rise high enough for steam bubbles to form. The first bubbles rise through the water, but eventually so many bubbles are forming and expanding as they rise that water is swept along or lifted by the bubbles, as in Old Faithful's preliminary spurts.

The lifting of a mixture of water and steam from the top of the column causes pressures to decrease at all depths. Some water then flashes to steam, much as gas is released when a bottle of warm soda pop is uncapped. A chain reaction starts that progresses rapidly downward, accounting for the explosive nature of many geysers.

If the geyser has a small plumbing system with channels that narrow abruptly with depth, this reservoir is soon emptied. But if the total volume of the system is large and is filled with water near its boiling point, it can feed an Old Faithful or other major geyser.

An eruption ends either when a geyser runs out of water or extra heat energy. Geysers that first run out of water then have a steam phase. If the geyser runs out of extra energy while water is still plentiful, the flow of steam decreases enough so that bubbles can again rise *through* the water without ejecting it.

The cycle starts again with accumulation of water and heat, until the system is "loaded" for another eruption.

Behavior patterns of geysers differ extremely because of construction differences in the natural subsurface plumbing. Whatever the type of geyser, formation of steam, resulting from sudden release of pressure at some point in its system, produces the eruption.

In every geyser the author has observed, water always rises in its tube before an eruption. In most geysers the rise is gradual; in some there is intermittent rise and fall.

In a few geysers where the rise is gradual, the degree of rise is indicative of the probable time of eruption. In others the rise of water in the crater comes suddenly, almost simultaneously, with the eruption. Splashes preliminary to an Old Faithful eruption indicate the rise of the water in its well.

Source of the water

Allen and Day, under sponsorship of the Carnegie Institution of Washington, made a special study of "rainfall and the discharge of hot springs"[3] in connection with other investigations. They concluded most water issuing from the springs is of "surface origin"—about 85 per cent meteoric (returned rain and snow water), and the remaining 15 per cent magmatic (reaching the earth's surface for the first time).

More recent studies suggest that the percentage of magmatic water is much lower. Isotopic studies on the origin of hot spring waters and steam by use of "natural isotopic tracer techniques," failed to show any "positive isotopic evidence for any juvenile or magmatic water in any hot spring system we have studied. The acid sulphate springs appear to be evaporated meteoric waters perched above the normal ground water table."[4]

Dr. White states that evidence indicates not more than five per cent of the water is magmatic—probably less. This percentage is inadequate to account for the great evolution of heat from the hot springs.

After extensive study and observation of the hot springs it is the author's opinion that the greater portion of the water from Old Faithful's eruption is meteoric. Magmatic water is a very small fraction of the whole.

Source of the heat

Geysers are found only in regions of rocks with volcanic origin. They are associated with an intermittent or dying phase of volcanic activity. Long after volcanism ceases, gases still discharge at and near the site of the lava extrusions.

Until recent investigations by the U.S. Geological Survey, it was theorized that gases issuing from magma supplied heat for Yellowstone's hot springs. But isotopic studies indicate that the amount of magmatic gas (steam) is inadequate to account for the heat in Yellowstone's hot springs. This heat, in excess of 840 million calories per second, is enough to melt one million tons of ice per day.

Deep drillings in many places in the world reveal that surface water penetrates to great depths, far below the depth of lava flows overlying Yellowstone country. Several thousand feet in the earth water comes in contact with very hot rock heated by near contact with magma which in the past poured great quantities of lava over the Yellowstone region.

Why an Old Faithful eruption stops

The Deep Circulation Theory assumes that activity ceases because the energy available for the eruption has been exhausted: the discharge of water and steam has been more rapid than the source could continue to furnish.

In most Yellowstone geysers there seem to be other factors involved than merely exhaustion of the energy supply. Practically all geysers are situated in basins that have an abundant supply of ground water.

Long, careful observation suggests that a number of the geysers cease activity when relatively cold ground water pours into the erupting mechanism. Some geysers, such as Castle and Lone Star, apparently terminate eruptions due to exhaustion of an immediate energy supply.

Most Yellowstone geysers are connected underground with nearby springs and geysers. This affords direct access of cooler water into the common plumbing. A drop in water level in connected springs at the time of an eruption demonstrates that water flows into the plumbing of the erupting geyser. Following an eruption, refilling of all springs is simultaneous.

Numerous large and small mounds closely surround Old Faithful. Inferences drawn from other closely grouped springs make it highly probable Old Faithful has subterranean connections with its family of mounds. During a seismic study of Old Faithful, seismic impulses were recorded on top of these mounds simultaneously with the eruption. When geophones were placed on the ground near the mounds no impulse was recorded. Thus, there must be a number of side channels leading from Old Faithful's main well.

It is the author's opinion that the influx of water from side channels is the direct cause of cessation of activity. At times this influx is rapid, resulting in a short period of play and an ensuing interval of underaverage length.

Numerous examples indicate many geysers do not always erupt all the water accessible to their main wells. Yellowstone's Daisy is a classic example of a geyser whose activity taps but a fraction of the water in underground cavities or fissures to which its plumbing leads.

CHAPTER IV

OLD FAITHFUL NEVER MISSES AN ERUPTION

Almost every season a few visitors stoutly maintain Old Faithful missed an eruption. They claim to have watched the geyser for a time equivalent to two eruption periods before it played.

When such rumors are thoroughly investigated, it has been found in most cases that they had not maintained the long and uninterrupted vigil claimed, but left after observing an eruption, returning in what was considered ample time for the next eruption. During their absence the geyser played on a very short interval. Unaware of Old Faithful's highly variable nature and that they had missed an eruption, the visitors waited for what seemed a time interval equal to two periods, convinced that the geyser had not erupted.

However, occasionally Old Faithful does have a very long interval which would imply that an eruption was missed. The U.S. Geological Survey in cooperation with the National Park Service has, since 1972, had a heat sensor directed toward the geyser which detects and records each time that Old Faithful plays. This surveillance, coupled with visual observations, has produced a more accurate picture of its behavior.

Intervals up to 148 minutes have been recorded by the sensor. Preliminary data suggests that low spurts, called preplay, or boiling underground at depth some-

times relieve pressure before enough energy is available for the geyser to erupt. A period of time is then required for pressure and heat to be restored in the geyser tube before it can erupt.

This process can be repeated several times. Thus, Old Faithful never misses an eruption; it sometimes just puts it off for awhile.

Even when one of Old Faithful's intervals runs two hours, it cannot be said the geyser missed an eruption. Neither can it be said eruptions come early, nor that they are overdue. While the time when Old Faithful will play cannot be stated without definite qualifications, the geyser is *never* in error. Eruptions are always on time — Old Faithful's time. Just what that time is has remained an enigma since the geyser was discovered. It is man's prediction of the time of the next eruption that is frequently in error.

Old Faithful is not measurably slowing down

When people learn Old Faithful is irregular in time of its play, this is frequently interpreted as an indication the geyser is slowing down. One cannot mingle with the crowds awaiting an eruption without hearing the "slowing down" opinion expressed.

Let's look at the facts. Not only is the length of Old Faithful's intervals quite variable, but the length of its seasonal average fluctuates from year to year. A comparative study of seasonal averages, in connection with daily behavior patterns, should reveal any noticeable trend in its function during the time it has been under observation.

The following interval table was compiled by Philip Fix, U.S.G.S. Calculation of intervals "include only those observations known to be reasonably accurate and whose method of calculation is known."

Interval Between Initiation of Eruptions, Old Faithful Geyser, 1870-1947[5]

Year	Observer	Eruptions Seen	Minimum	Interval Maximum	Average
1870	Doane				50m
1870	Washburn				60m
1872	Peale	17	65m 00s	70m 34s	67m 54s
1873	Comstock	11	52m 05s	77m 35s	63m 48s
1875	Dana and Grinnell	24			65m-66m
1877	Sherman and Poe	7	62m	80m	67m
1878	Peale	97	54m 04s	78m 00s	65m 06s
1879	Mitchell				70m
1879	Seguin				45m
1883	Hallock				65m
1928	Allen and Day	6	57m 30s	74m	
1928-9	Baker	38	58m 20s	75m	
1932	Robertson	1187	38m	81m	65.7m
1937	Fix (July 17)	2		84m	
1937	Fix (Aug. & Sept.)	23	42m 58s	79m 47s	67m 38s
1938	Woodward	771			66m 30s
1939	U.S.N.P.S.	500	40m	86m	66.1m
1940	"	1075	39m	87m	67m
1941	"	1577	38m	91m	66.3m
1942	"	1452*	41m	90m	60.05m*
1943	"	376	39m	84.5m	63.45m
1945	"	940	39m	85m	63.77m
1946	"	1495	34m	86m	63.2m
1947	"	1500	39m	89m	63.3m
1870-1947		11098	34m	91m	65.12m

(11096 used to calculate average interval)

*During the 1942 season 1638 eruption intervals were recorded. Average interval for the season was 65.8 minutes. The discrepancy between above figures for the 1942 season and those found in the table no doubt resulted from Fix's not having access to all of the records. It would seem that the seasonal average of 60.05m given by Fix is either a mathematical or typographical error.

Since compilation of the tables in 1947, records for 26 additional summers and 8 winters have accumulated as a result of observations made by Park Service employees. A portion of these records are shown in the following table. Each section represents data for a five year period with the exception of 1973.

Year	Eruption Intervals	Minimum	Interval Maximum	Average
1948-52	9340	33	88	63.3
1953-57	6233	35	93	64.3
1958-62	10958	33	95	65.3
1963-67	8587	35	96	65.9
1968-72	9319	33	96	64.8
1973	2562	35	148	66.3
1948-73	46999	33	148	64.8

From 1948 through 1973 over four times as many eruption intervals are cited in the tables as for the previous 77 years. However, many more eruption intervals were recorded between 1870 and 1948 than are included in the table by Philip Fix. Unfortunately, some of these records have been lost. The 4381 eruption intervals which were determined for 1960 are the maximum number recorded for any one year.

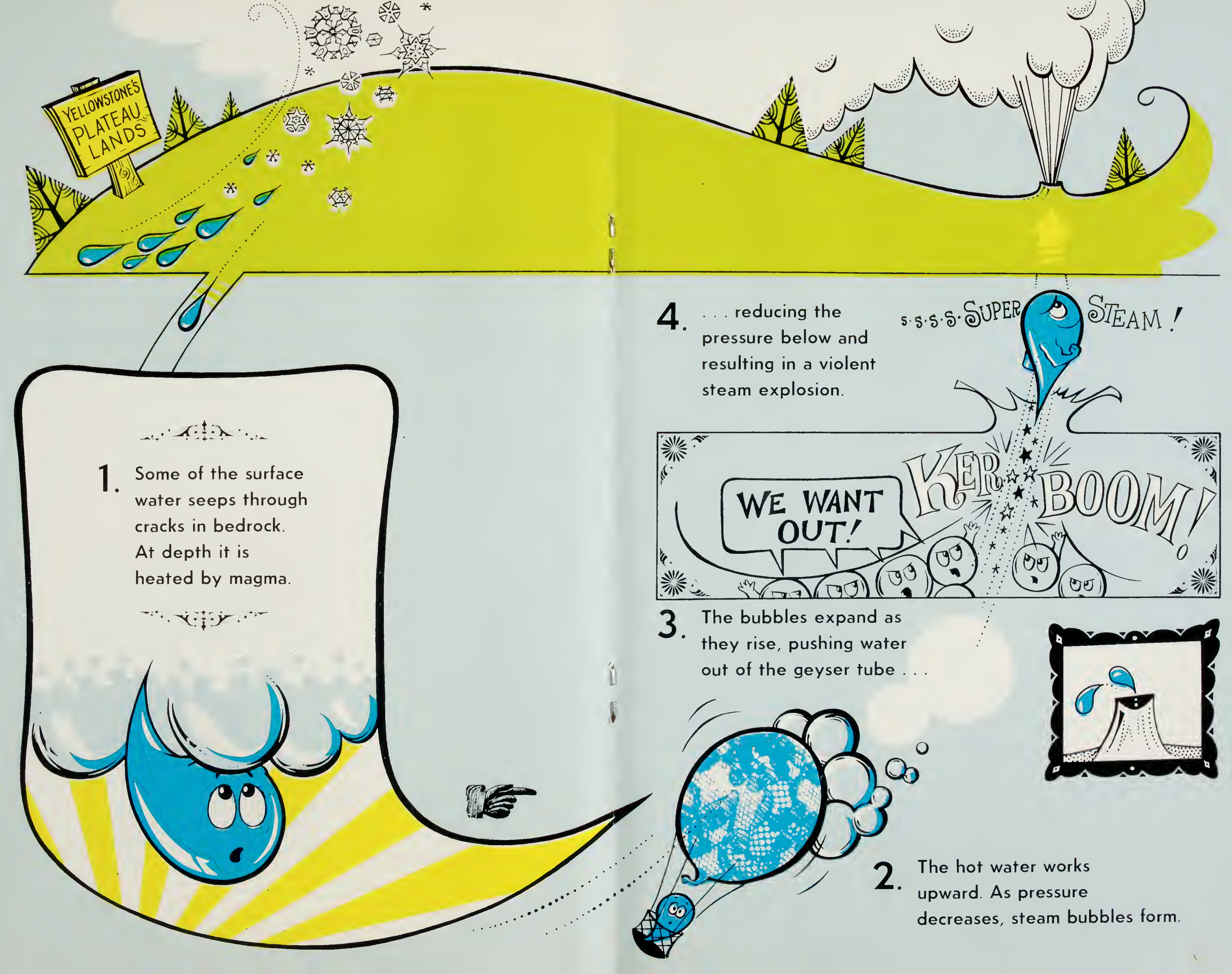
During 16 years preceding the 1959 earthquake, Old Faithful's seasonal average was consistently under that revealed by earlier records. It may be there are cyclic periods when the average eruption interval is shorter, with recurring periods of an increase in average time. Extension of present methods of recording will show whether or not this is the case. It is worth noting that the shortest interval on record, 33 minutes, was first obtained during the 1948 season. Similar 33-minute intervals were also noted during 1950, 1951, 1959 and 1968.

It is doubtful whether Old Faithful, or any geyser, has been observed long enough to say with any degree of finality just what its interval trend might be. If existing records covered a much longer period, or if more detailed records had been made

and kept, comparative data then would no doubt be ample for accurate deduction.

During the period Yellowstone geysers have been observed, some have continued to play on essentially the same pattern as when they were first discovered. The majority, however, have been spasmodic in activity, showing great irregularities. Observation is slowly revealing that the vacillating function of many geysers is cyclic in occurrence, and may represent a pattern as definite as Old Faithful's.

The hypothesis of a cooling earth has given force to the opinion that there is a gradual decline in geyser activity. Records to date furnish no evidence that any measurable decline has taken place since Old Faithful's discovery. Geologically there is suggestion that Yellowstone's thermal areas still are recovering from the destructive effects of glaciation. So far as intensity of hydrothermal activity is concerned, there is compelling evidence to support the thesis that its climax has not been reached since its emergence from the last glacial epoch.



1. Some of the surface water seeps through cracks in bedrock. At depth it is heated by magma.

2. The hot water works upward. As pressure decreases, steam bubbles form.

3. The bubbles expand as they rise, pushing water out of the geyser tube . . .

4. . . . reducing the pressure below and resulting in a violent steam explosion.

CHAPTER V

HEIGHT OF ERUPTIONS

Many folks comment that Old Faithful is not playing as high now as it did when they first observed it on an earlier visit. Their hastily drawn conclusions are passed to others, resulting in widespread misconception.

Without doubt, the natural enthusiasm of first impressions is a big factor in accounting for their claims. But their contention has some validity when one considers the wide variations in the geyser's eruption height, both apparent and real.

By actual measurement, eruptions of Old Faithful vary in height from 106 to 184 feet.

Factors influencing height impressions

Atmosphere and subterranean conditions influence Old Faithful's height. Weather not only plays an important role in the height of an eruption, but profoundly effects the casual observer's impression of height.

Should a visitor chance to see an eruption when the air is cool, still and humid, he will tell a different story from someone who saw an eruption when

the air was dry, warm and with a strong wind blowing. While the initial subterranean force might be the same for both eruptions, the real fountain height, and particularly the impression of height, would differ drastically.

When the air is still, cool and humid, large condensing clouds of steam spread out and hover around the water column. Above the column these clouds sometimes ascend vertically in rolling cauliflower-like masses for several hundred feet. The impression of such an eruption differs greatly from the impression of one that takes place when the air is warm and dry. This eruption results in little condensation of the steam. If a strong wind is blowing, from 20 to 30 feet will be sheared from the top of the water column.

Although weather plays an important part in the apparent power display of Old Faithful, only the real variations in height are considered for record keeping purposes. Such measurements must be taken when the atmosphere is comparatively quiet.

Old Faithful's eruption height varies

Data on variations in eruption magnitude are much less complete than on its interval variations. Only periodically have eruption heights been mathematically determined. At no time has the height of many consecutive eruptions been measured. While objective data are not as complete as desirable, they are adequate, especially when augmented by the vast amount of general observation on height variation.

Today the height Old Faithful or any geyser plays is considered to be the top of the highest splash of water. Early observers measured only the top of the uppermost mass of the unbroken water column. Measurement of height depends upon the principle of similar triangles. The problem is one of ordinary proportion. The following table shows the

measured height of a few eruptions of Old Faithful, 1870-1947, as compiled by Philip F. Fix, U.S.G.S.[5]

			Height of eruption (feet)		
Year	Observer	Eruptions Measured	Minimum	Maximum	Average
1871	Barlow	?	?	138	?
1872	Peale	5	106	130	122
1875	Dana and Grinnell	24	?	?	115
1878	Peale	11	106	139	125
1910	Haynes	5	?	?	150
1928	Allen and Day	6	114	150	133
1928-9	Baker	38	110	160	?
1937	Fix	19	111	184	146
1871-1878		40	106	139	119
1928-1937		63	110	184	143
1870-1947	Summary	108	106	184	130

This table shows that highest measurements have been obtained in recent years. Though a different focal point for measuring height has been used the past 20 years than during the first decades of Old Faithful's history, the difference between these points falls far short of equaling the maximum height differences between early and recent measurements.

Variations of from one and one half to five and one half minutes in the duration of Old Faithful's eruptions suggest that some eruptions may be more powerful than others. The duration of the activity has a direct influence on the height. An eruption of two minutes duration is rarely as high and powerful as the succeeding one which comes only after a greater-than-average lapse time and lasts from four to five minutes. The greater height at the end of the greater-than-average interval probably results from an increased amount of water being heated to the critical temperature for the eruption.

CHAPTER VI

OLD FAITHFUL'S WATER AND CONE

During each eruption Old Faithful discharges water at a temperature in excess of 200 degrees Fahrenheit. Recent measurements indicate that the amount is on the order of 4,000 to 7,000 gallons.

Like all water issuing from the earth, Old Faithful's water contains mineral matter. Analysis indicates it amounts to about 1.47 grams per liter, or about 65 pounds for each eruption. This is not unusual; many cold springs contain an equivalent concentration of solid matter. Old Faithful's water contains no minerals in sufficient quantity to make it unfit for drinking. When cooled it tastes like ordinary boiled water.

Such purity is not true of all Yellowstone hot springs. A few contain considerable amounts of arsenic. In others the water tastes brackish due to salts of such metals as magnesium. The odor is due to hydrogen

Large cauliflower-like masses of geyserite guard the vent of Old Faithful. A terraced pattern, due to an earlier hot spring stage, remains evident on one side of the geyser's cone. (Photo: Canter)

sulphide, a gas found in quantities of less than one part in 3,000 in Old Faithful's water. This water contains no free sulphur.

Neither the water of Old Faithful nor water from any hot spring in the park is used for utilitarian purposes. A few people are disturbed that the great power potential of Yellowstone's thermal wonders is not put to "practical" use. To do so would be to destroy them, as it has in other major geyser and hot spring areas in the world. Furthermore, preservation of the total environment including all its natural features is fundamental to the basic purpose of the National Parks.

Geyser's cone and mound are deceptive

While Old Faithful's mound presents a circular appearance, its basal portion is oblong with the major axis lying northeast and southwest. The original perimeter is largely effaced by erosion. From where the mound starts to rise, the perimeter is 615 feet. The cone "rises 11 feet and 11 inches above its base."[6] The generally flattened cone top is oval-shaped with the long axis lying east and west; dimensions of the top measure 21 by 41.8 feet. On the north and west sides there is a decided terraced pattern, which shows little alteration from its pre-Old Faithful state.

About two-thirds of the mound's southwestern exposure is covered with a beautiful fretwork of geyserite, formed into beads and spicules. The remaining one-third to the northeast presents a scoured appearance. There are numerous collecting basins on the southwestern two-thirds of the mound, most of them shallow, but near the vent they range from 8 to 18 inches in depth and have lovely scalloped borders. Deeper basins contain near-boiling water which is replenished during each eruption.

Next to the vent on the west and northwest sides, large cauliflower-like masses of geyserite rise

Inside the two cave-like openings in the large mounds near Old Faithful's vent are tree stumps which serve as nuclei for encrusting geyserite (Photo: Watson). Below, close-up view of Old Faithful's vent. (Photo: Condon)

48 inches above the part of the mound on which they rest and 30 inches above the flat top of the cone. Tree sections have served as nuclei for the incrusting geyserite forming these protuberances.

Many tree stumps and sections are embedded in the geyserite forming the mound. Erosion also is exposing great quantities of embedded pine needles and both the pistillate and staminate cones of the Lodgepole Pine which at one time grew over the mound.

The crater is on the extreme western side of the mound's top. Like the top of the cone, the crater is

oblong, measuring 90 by 64 inches at its top. Eighteen inches below the top it constricts to the main vent which is 60 by 23 inches. The main vent, in the form of an antechamber, extends downward nine feet where it encounters a fissure from four to eight inches wide of undetermined length. The fissure lies in the direction of the axis of the cone's top. At one time this fissure, of which Old Faithful's crater is a part, extended from the main vent to the base of the mound on the east side. The break, except for a small steam vent, now is filled with sinter.

Minerals found in the cone

Old Faithful's cone is composed of a mineral known as geyserite ($SiO_2.nH_2O$). This whitish-gray mineral covers much of the ground in the geyser basins. Its bleached coloration is suggestive of limestone, but the mineral composition of limestone, ($CaCO_3$), is very different.

The term geyserite tells nothing about its composition. Silicious sinter, another term for this mineral, is more descriptive and indicates silicon is its principal element.

Chemically, geyserite is about the same composition as quartz, one of the hardest rocks. But it contains water in its molecules, making it softer than quartz. Depending upon its mode of formation, geyserite ranges from highly porous to quite dense, though its density and hardness are less than petrified wood.

Scalloped borders decorate the edges of the pools of scalding water that surround the vent of Old Faithful. (Photo: Canter)

CHAPTER VII

1959 EARTHQUAKE AFFECTS OLD FAITHFUL

The Hebgen Lake earthquake of August 17, 1959, had a profound effect upon the majority of hot springs along the Firehole River. It resulted in marked alterations in the functional behavior of many springs. Immediately following the earthquake there was noticeable increase in thermal energy. In general, all springs became hotter; many geysers began erupting on shorter intervals. On the other hand, major geysers such as Giant, Splendid, Daisy and Morning became dormant; in some, dormancy has persisted.

Many alterations in hot-spring activity were delayed. Days, weeks and sometimes months passed before changes became evident. In fact, a number of groups of springs in the geyser basins still are in the process of change. It seems likely that years will elapse before there will be an end to the changes that were started by the 1959 earthquake.

During the first few days following the big tremors of that August night in 1959, it was thought Old Faithful had escaped unscathed. The character and frequency of its eruptions were essentially the same.

But by the end of August the average interval had increased one minute over the pre-quake average. This was not particularly significant, since short-term deviations in average time are not uncommon. However, during succeeding months there was a progressive increase in average time. The amount of this increase cannot be ascribed to seasonal fluctuations. From August 17 to the end of the year Old Faithful's average interval increased from 60.8 minutes to 67.4 minutes. There is no record of any previous fluctuation of such magnitude occurring in so short a period.

After progressive increase through December, the average time for all of 1960 stabilized somewhat at 66.3 minutes. Since 1960 the average interval has varied between 64 and 67 minutes.

The increase of between five and six minutes in Old Faithful's average eruption time must be ascribed to some apparently minor change resulting from the earthquake. Based on inter-functional behavior patterns known to exist between hot-spring groups, Old Faithful's slight loss in thermal energy may have resulted from a minor shift of its eruption potential to some nearby hot spring. As with many thermal springs in the Firehole Geyser Basins, considerable time will probably pass before all latent effects of the 1959 earthquake become fully manifest in Old Faithful.

The 1959 earthquake is not the first major disturbance to occur in the geyser basins. Seismic records reveal that earthquakes are frequent in Yellowstone country. In fact, Old Faithful probably owes its origin to an earthquake. The large crack across the mound from which it issues strongly supports this premise. Prior to 1959, however, no quake of record

was of sufficient intensity to produce attributable hydrothermal changes.

While man has no records of other major earthquakes in Yellowstone, nature bears mute testimony that such disturbances have occurred. When gigantic boulders were shaken loose and cascaded into canyons in 1959, it was noted that weathered rocks of similar size and shape were lying beside them. Some of the boulders were at even greater distances from the cliffs. Evidence seems compelling that these lichen-covered boulders were brought down by earthquakes whose force was equal to or greater than the 1959 earthquake.

There is abundant evidence that earthquakes have played an important role in the evolution of the geyser basins. A number of new geysers had their genesis as a result of the 1959 disturbance. Apparently the hot springs have been subjected to major alterations over the years. Many old fractures in the geyserite through which some of the springs issue were probably caused by earthquake activity.

Seismic study of Old Faithful

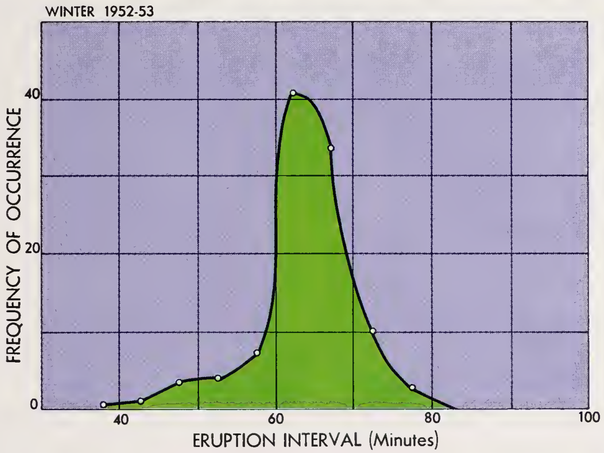
In 1965 John S. Rinehart began a study of earth tremors generated by Old Faithful. During 81 complete eruption cycles his instruments registered the seismic pulses.

Somewhat different types of sequence in signals were noted, depending upon whether there was a long or short interval. For short intervals, seismic signals began immediately following the eruption, while for long intervals there was an absence of tremors for at least 20 minutes.

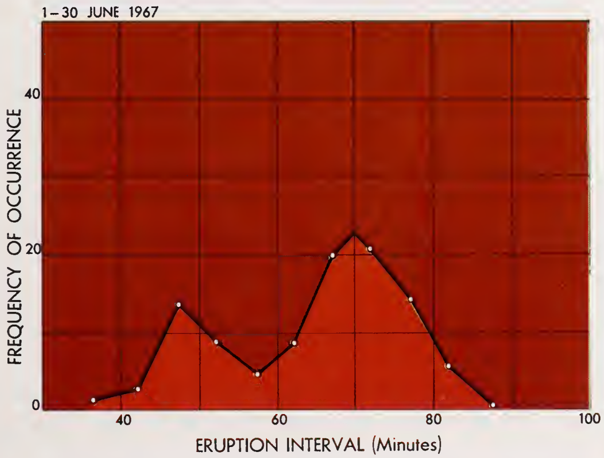
During "typical" short intervals there were about 120 strong pulses; for the long intervals, 140. Tremors noted in Old Faithful during its quiet phase are probably due to the collapse of steam bubbles in the system.

In addition to the studies of earth tremors generated by Old Faithful, Dr. Rinehart plotted many frequency distributions of the intervals. These graphs (see below) indicate that prior to the 1959 earthquake there were relatively few short intervals but these became more numerous following the disturbance. Thus the pattern of two types of eruption—long and short—became more pronounced after the earthquake.

TYPICAL BEHAVIOR BEFORE 1959 QUAKE



TYPICAL BEHAVIOR AFTER 1959 QUAKE



CHAPTER VIII

ESTIMATED AGE OF OLD FAITHFUL

Estimates of Old Faithful's age vary widely. This disparity results from failure by early students to correctly interpret Old Faithful's mound.

The amount of sinter deposited around a hot spring's orifice often is assumed to be a measure of the geyser's age. With the spring's present estimated rate of deposition as a measuring stick, scientists then compute how long it took that spring to build up the mass of sinter surrounding its vent.

This method has a number of weaknesses, mainly that hot springs, which also deposit sinter, often precede the formation of a geyser. Thus, the bulk of sinter about orifices of many geysers was deposited by some earlier hot spring whose behavior was very different.

Measurement of Old Faithful's mound in 1878 by the Hayden Survey showed it to be 145 by 215 feet

at the base, 20 by 54 feet at the top, and 11 feet, 11 inches high.

When the slow rate of growth or deposition of sinter is considered, it is probable that several thousand years would be required for the growth of a mound this size.

Old Faithful did not build its mound

A critical inspection of Old Faithful's mound reveals that a hot spring with a functional behavior like Old Faithful's never could build a mound of this shape. The cone has a terraced pattern on the north and east sides. But geysers with eruptive patterns like Old Faithful's do not build terraced mounds.

Before Old Faithful began playing as a geyser the terracing would have been symmetrical around the cone. Today these terraces are not as evident on the south and west sides where they are partially filled by deposition from Old Faithful. Sections of terraces, once visible on the east side of the cone, have been washed away by the force of falling water from eruptions. The vent, while at the top of the mound, is on the extreme west side—out of balance with the rest of the cone. Old Faithful, playing as it does today, would not have built such an unbalanced mound.

When active deposition of geyserite takes place, it is firm and hard, and assumes the shape of nodules, beads or spicules. On the northeast and east sides of Old Faithful's mound are no such geyserite deposits. Instead, active erosion of these sides is taking place. The geyserite at the base of the cone on the east and south sides is fragmental and broken, and weathered sinter erosion channels have formed. From the base of the mound, extending outward on all sides, erosion channels steadily deepen.

Since Old Faithful began playing, it has eroded away more sinter from its mound than it has added. By far the greatest amount of erosion takes place in

Partially petrified wood of a lodgepole pine is encrusted in sinter of Old Faithful's cone. Erosion exposes other tree sections and stumps. (Photo: Douglass)

winter. This erosion has revealed, and still is uncovering additional evidence that Old Faithful did not build the house it occupies.

Imbedded in geyserite on all sides of Old Faithful's mound are partially exposed stumps and logs of many trees. These stumps and logs are more in evidence on the east side near the base where erosion is greatest. But they also can be observed at the very top of the mound. A large prostrate, highly silicified log forms the wall of one terrace near the top of the mound.

The large protuberances next to the vent of Old Faithful are tree stumps heavily incrusted with geyserite. Apparently many trees once grew on the mound. It would have been impossible for trees to have been growing here while hot spring activity was taking place. Rather, the partially exhumed logs and stumps are evidence of a long dormant period.

There's no doubt that trees will grow on a mound of geyserite. The large mound 300 feet east of

Old Faithful supports trees over its north and east sides. Old Faithful's mound would have presented a similar appearance at one time with even larger trees.

Tree stumps and tree sections now being exposed by Old Faithful's erosive water were interred by a hot spring antedating the present geyser. They also indicate at least two separate periods of activity with an intervening dormant period before Old Faithful came into being.

First, there was activity which built the cone to near its present dimensions. A long period of dormancy followed during which trees grew over the mound. The mound then was rejuvenated and an activity very different from Old Faithful's took place for a relatively long period. It was this activity that buried the logs and stumps and built the terraced structure.

This pre-Old Faithful hot spring has been designated "intermediate spring," and is considered a direct forerunner of Old Faithful. In discussing the origin of this spring and its relationship to Old Faithful, the author reported in the American Journal of Science: "The intermediate spring, which built the terraces and interred stumps and prostrate tree sections, began to flow when some mechanical adjustment broke the geyserite shield, thereby tapping arteries previously sealed off in their upper reaches. It did not follow the normal slow process of chemical development . . . This view is strengthened by the presence of innumerable pine needles and staminate and pistillate cones embedded in the geyserite deposited by the intermediate spring. A rather sudden extrusion of water from the cone, while the trees still were alive, seems required for the nearly perfect preservation of these specimens, particularly the staminate cones.

"Probably the intermediate spring had very different activity from Old Faithful, both because a

large section of the crack served as an orifice, and because one or more of the large neighboring cones were then active. Like other groups of closely spaced springs in Yellowstone, Old Faithful and its neighboring mounds seem to be connected subterraneously.

"Even if the mound passed through a dormant stage following the intermediate spring this stage must have been very short. Probably the intermediate spring was a direct precursor to Old Faithful, which assumed its present pattern of play at about the time one or more of the other connected springs, including a section of the crack, became choked with mineral accretion, diverting all the thermal energy to Old Faithful.

"The shape of the terraces provides additional evidence that Old Faithful now is erupting from a section of the intermediate spring's vent. The long axis of the cone's top is at a right angle to the basal axis, probably because water at the intermediate spring stage issued along the greater length of the crack at the top of the mound. A section of the crack, four feet east of the present office, is still a steam vent."[7]

The age of silicified wood buried in the mound gives a clue to Old Faithful's age. In September 1954, Dr. Harmon Craig of the Institute of Nuclear Studies, University of Chicago, sent a specimen of this wood to the U.S. Geological Radiocarbon Laboratory for Carbon 14 analysis. Results of the test gave an age to the wood of "730 plus or minus 200 years."

Thus, it is reasonably certain that the origin of the intermediate spring dates back to the time revealed by Carbon 14. The ratio of sinter added to the mound by this spring compared to the deposition from Old Faithful, indicates the intermediate spring was active approximately three times as long as Old Faithful. This would give Old Faithful a relatively youthful age of between 200 and 300 years.

CHAPTER IX

OLD FAITHFUL'S FUTURE

Old Faithful's activity is not decreasing. Since the geyser's discovery its pattern has been highly consistant. How much longer it will continue to play without showing senescence is largely speculation.

Many expect that Old Faithful will continue to play on its present pattern until cooling magma reduces the heat supply. This, they say, will result in lengthened intervals until eventually heat will be insufficient to raise water temperatures to the critical eruption point. Because of a supposedly cooling hearth, it has been generally held that the intensity of Yellowstone geyser activity is less today, though unrecognizable, than it was at time of discovery.

In the author's opinion the lifetime of any geyser is an infinitesimal fraction of the age potential of its heat reservoir. No geyser functions long enough for magmatic cooling to be a measurable factor in its aging.

It is becoming increasingly evident that the waning activity and decline of temperature are rhythmic in many hot springs. Complete rejuvenation follows cycles of lessened activity. The cause of most changes does not come from the source of the magmatic energy. Instead it is more superficial, resulting from diversion of thermal energy to some

other orifice with which the hot spring has subterranean connections.[8] Or it results from the development of a purely local condition that blocks transfer of heat energy to the surface.

There has been little or no observable progressive change in hot spring activity since Yellowstone was discovered. If observation could extend back far enough into the past it would be apparent that some geysers, active in an earlier period, became dormant before the Washburn party arrived in Yellowstone. Similarly, geysers that are active today would have been in an early stage of development, if they had appeared at all.

Large dormant mounds encircling Old Faithful are mute evidence of this changing activity. It is as certain that hot springs once issued from these dormant mounds as it is that a dead tree in the forest was at one time living. The degree of weathering of geyserite in different mounds clearly indicates some have been dormant longer than others. While Old Faithful's activity is a new function in this group, its mound could well be one of the oldest.

The structure of these mounds (the same can be observed for many mounds located in other parts of the geyser basins) reveals the activity which built them was brought to a close not by dwindling heat or water supply, but by self-destruction. Silicious sinter is deposited, not only at the surface, but like lime in a teakettle, grows internally in upper reaches of the plumbing of all geysers which have an alkaline-type water.

Examination of the dormant mounds fails to disclose any channels or wells leading into them. During building of these cones, their channels were slowly filled. In a few mounds concentric growth rings of geyserite mark the location of the former vents. Some of the mounds near Old Faithful may have been active simultaneously. While one or more of the hot springs in this group were closing their

vents, shutting off the flow of water, a new development was no doubt taking place at the site of one of the other mounds.

A successor to Old Faithful

Deposition of geyserite at or near the vent of Old Faithful is slowly sealing it off, just as the springs in the other mounds have been closed. As this happens, we may expect another spring to evolve.

The mound whose base abuts Old Faithful's on the northeast, has been dormant longer than any other in the group, judged by weathering of its geyserite. This could be the site of the evolution of a new spring or geyser that may well be a successor to Old Faithful—not necessarily an Old Faithful.

In winter bison, showing no fear of the geysers, move into the geyser basins to find sustenance. (Photo: Canter)

On the northeast flank of this mound is a large, active fumarole or steam vent. The ground is acid instead of alkaline as with the other mounds. At the site of the fumarole chemical evidence suggests that there is acid decomposition of the underlying rhyolite with resulting solution or leaching.

If leaching persists, it is likely that water eventually will find its way to the surface. Should the water be connected with Old Faithful's supply its issuance from another vent could mark the end of Old Faithful's high degree of constancy. Like other geysers in the basin with underground connections to one or more springs or geysers, Old Faithful then would show great irregularity with occasional dormant periods.

Old Faithful's present high degree of regularity is largely the result of it being a self-contained unit. Thermal energy belonging to Old Faithful's family group of mounds now is confined primarily to Old Faithful. Any development of a new spring or geyser connected underground with it would likely result in Old Faithful's departing from its present eruptive pattern. It is possible a major earthquake could initiate a new geyser in one of the now dormant mounds.

Just as Old Faithful's mound was not always the active one in this group, it is reasonable to assume that it will again become dormant. If the magmatic energy persists long enough, Old Faithful will be replaced by a new hot spring or geyser.

Old Faithful's function is the most recent expression of geyser activity in these mounds, but physical evidence is compelling that at no time since the start of hot springs in this group of mounds has there been an intensity of geyser activity equal to Old Faithful's.

One cannot become acquainted with Old Faithful without gaining confidence that Yellowstone will offer a geyser spectacle for a long time to come.

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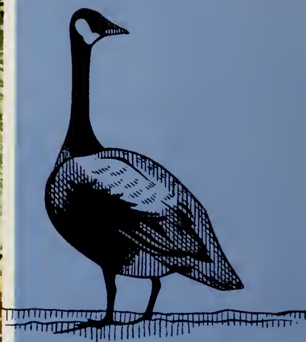

Petrified wood

Geyser cone